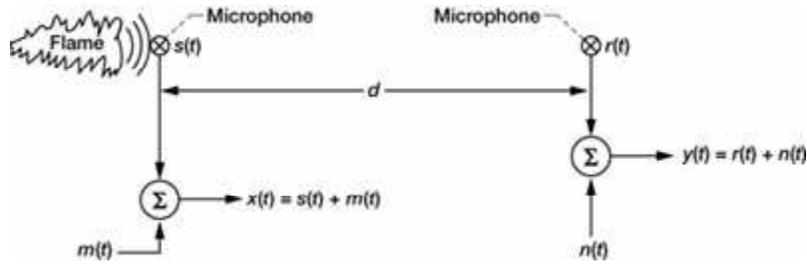


Acoustic Pyrometry Applied to Gas Turbines and Jet Engines

Internal gas temperature is one of the most fundamental parameters related to engine efficiency and emissions production. The most common methods for measuring gas temperature are physical probes, such as thermocouples and thermistors, and optical methods, such as Coherent Anti Stokes Raman Spectroscopy (CARS) or Rayleigh scattering. Probes are relatively easy to use, but they are intrusive, their output must be corrected for errors due to radiation and conduction, and their upper use temperature is limited. Optical methods are nonintrusive, and they measure some intrinsic property of the gas that is directly related to its temperature (e.g., lifetime or the ratio of line strengths). However, optical methods are usually difficult to use, and optical access is not always available. Lately, acoustic techniques have been receiving some interest as a way to overcome these limitations (ref. 1).

One of these techniques, acoustic pyrometry, is also nonintrusive, is simpler to use than optical pyrometry, and doesn't require optical access. To measure the mean gas temperature between two points, one places a sound (acoustic) source at one point and a microphone at a known distance from the source, then measures the time required for the signal to travel from the source to the microphone. The speed of the sound is the distance divided by the time of flight, and it is directly proportional to the square root of the absolute temperature of the gas.

Measuring gas temperature in the noisy environment of a jet engine, however, might require a very powerful sound source. Instead, an experiment was performed at the NASA Lewis Research Center in collaboration with the University of Nevada at Reno (UNR), to determine the feasibility of using the combustion noise itself as the sound source (ref. 2). The experiment consisted of installing two microphones downstream of the combustion zone of a burner rig, measuring the time of flight of the signal, and calculating the gas temperature. The setup is shown schematically in the accompanying figure. Since no signal was externally introduced at the upstream location, the time of flight had to be determined from the cross correlation of the signals from the two microphones. The upstream and downstream signals were recorded on a two-channel digital audio recorder and processed at the University of Nevada at Reno to calculate the cross correlation between signals $s(t)$ and $r(t)$ and to remove the uncorrelated noise $n(t)$ and $m(t)$, as shown in the figure (where t indicates time). The shape of the cross-correlation function indicated that the signals consisted of wideband random noise. The measured speed of sound for this particular experiment was 787 m/sec, which corresponds to 1270 °C.



Measurement of sound speed using two microphones.

Future work will include experiments to determine whether the various operating conditions of an engine have distinct acoustic signatures, raising the possibility of acoustic combustion monitoring as well as temperature measurement.

References

1. Kleppe, J.A.: High Temperature Gas Measurements Using Acoustic Pyrometry. Sens., vol. 13, no. 1, Jan. 1996, pp. 17-22.
2. Kleppe, J.; Sanches, J.; Fralick, G.: The Application of Acoustic Pyrometry to Gas Turbines and Jet Engines. AIAA Paper 98-3611, 1998.

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